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New Energy Times Archive

06/05/89
R.L. Garwin

Cold Nuclear Fusion (?)

CERN

- 1) First papers (U.U. & B.Y.U.)
- 2) "Theory"
- 3) More recent results.
- 4) Conclusions
(what to look for)

Research Report

Electrochemical Experiments in Cold Nuclear Fusion

J. F. Ziegler, T. H. Zabel, J. J. Cuomo, V. A. Brusica,
G. S. Cargill III, E. J. O'Sullivan and A. D. Marwick

IBM Research Division
T.J. Watson Research Center
Yorktown Heights, N.Y. 10598

→ *Phy. Rev. Lett.*
04/18/89

PREPRINT SUBMITTED TO: Europhysics Letters

EVIDENCE OF EMISSION OF NEUTRONS FROM A TITANIUM-DEUTERIUM SYSTEM

A. De Ninno, A. Frattolillo*, G. Lollobattista, L. Martinis, M. Martone*, L. Mori,
S. Podda*, F. Scaramuzzi

ENEA, Dip. TEB, U.S. Fisica Applicata, Centro Ricerche Energia Frascati,
C.P. 65 -00044 Frascati, Rome, Italy

ARTICLES

Observation of cold nuclear fusion in condensed matter

S. E. Jones*, E. P. Palmer*, J. B. Czirr*, D. L. Decker*, G. L. Jensen*,
J. M. Thorne*, S. F. Taylor* & J. Rafelski†

* Departments of Physics and Chemistry, Brigham Young University Provo, Utah 84602, USA
† Department of Physics, University of Arizona, Tucson, Arizona 85721, USA

When a current is passed through palladium or titanium electrodes immersed in an electrolyte of deuterated water and various metal salts, a small but significant flux of neutrons is detected. Fusion of deuterons within the metal lattice may be the

rate will be an upper limit; on the other hand, if fusion-produced ^3He is stored in the mantle (so that the outward flux does not equal the production rate), our value will be a lower limit. As each p-d fusion produces one ^3He atom, and as the isotopic abundance of deuterium in water is $\sim 1.5 \times 10^{-4}$ deuterons per proton, we infer a geological fusion rate constant, λ_f , of

$2 \times 10^{19} \text{ } ^3\text{He atoms s}^{-1}$

Nature
04/27/89

blätterfrage MARCHAND zu entsprechenden Feststellungen am Objekt, wie auch zu Ausführungen allgemeiner Natur veranlaßten (1899). Bei den Mißbildungen liegt das Interesse vor allen Dingen in der Art ihres Zustandekommens und auch hier griffen MARCHANDS Erklärungsversuche aus, indem sie die Ergebnisse von Wirbeltieren und Wirbellosen mentelle

wie der Verlauf der nächsten beiden Jahrzehnte erwies.

Die wissenschaftliche Retikulation MARCHAND aller

Cold Fusion In Isotopic Hydrogen Molecules

S. E. Koonin* and M. Nauenberg**

Institute for Theoretical Physics
University of California

Santa Barbara, CA 93106

Submitted to Nature, April 7, 1989

Two Innocent Chemists Look at Cold Fusion

Cheves Walling* and Jack Simons*

Chemistry Department

University of Utah

Salt Lake City, Utah 84112

Stellung für die weitere wissenschaftlichen Tätigkeit förderlicher sei und damit hat er wohl recht gehabt,

MARCHAND zu den besten und edelsten. Heute seien ihm für seinen Lebensabend die herzlichsten Wünsche dargebracht; möge ihm seine Schaffensfreudigkeit auch fernerhin erhalten bleiben, denn arbeiten und der Wissenschaft dienen galt ihm stets als das höchste und so wird es bleiben bis ans Ende.

Über die Verwandlung von Wasserstoff in Helium¹⁾.

Von FRITZ PANETH und KURT PETERS, Berlin.

(Aus dem Chemischen Institut der Universität.)

1. Der Grundgedanke der Arbeit.

In den modernen Fassungen der PROUTschen Hypothese, in den astro-physikalischen Berechnungen der Lebensdauer der Fixsterne und in den radioaktiven Überlegungen über den Ursprung der HESSschen Strahlung wird stets auf die theoretisch zu fordernde Verwandlungsmöglichkeit von Wasserstoff in Helium hingewiesen. Diese Elementverwandlung zu realisieren, ist aber bisher nicht gelungen, obwohl bereits mit den verschiedensten

¹⁾ Berichte der Deutschen Chemischen Gesellschaft Jg. 59, Nr. 3, S. 2039. Die Erlaubnis zum Abdruck der Arbeit haben Die Naturwissenschaften dem Vorstände der Deutschen Chemischen Gesellschaft und der Schriftleitung der Berichte zu danken.

Arten elektrischer Entladungen unter Zufuhr großer Energiemengen daran gearbeitet worden ist.

Nun ist die Reaktion selber vermutlich in höchstem Maße energieliefernd; aus der Massenabnahme der 4 Grammatome Wasserstoff beim Übergang in Helium berechnet sich eine Wärmetönung von $6,4 \times 10^{11}$ cal. Es ist daher gar nicht sicher, daß überhaupt Energie zugeführt werden muß, um die Reaktion zum Ablauf zu bringen. Eine andere Möglichkeit, die Reaktion nachweisbar zu machen, könnte darin bestehen, daß man die an und für sich unmeßbar langsam verlaufende Elementverwandlung katalytisch beschleunigt. Der Grundgedanke unserer Arbeit war daher, zu prüfen, ob sich Wasserstoff-ohne Energiezufuhr

teilweise in einem geei und zwar Palladium

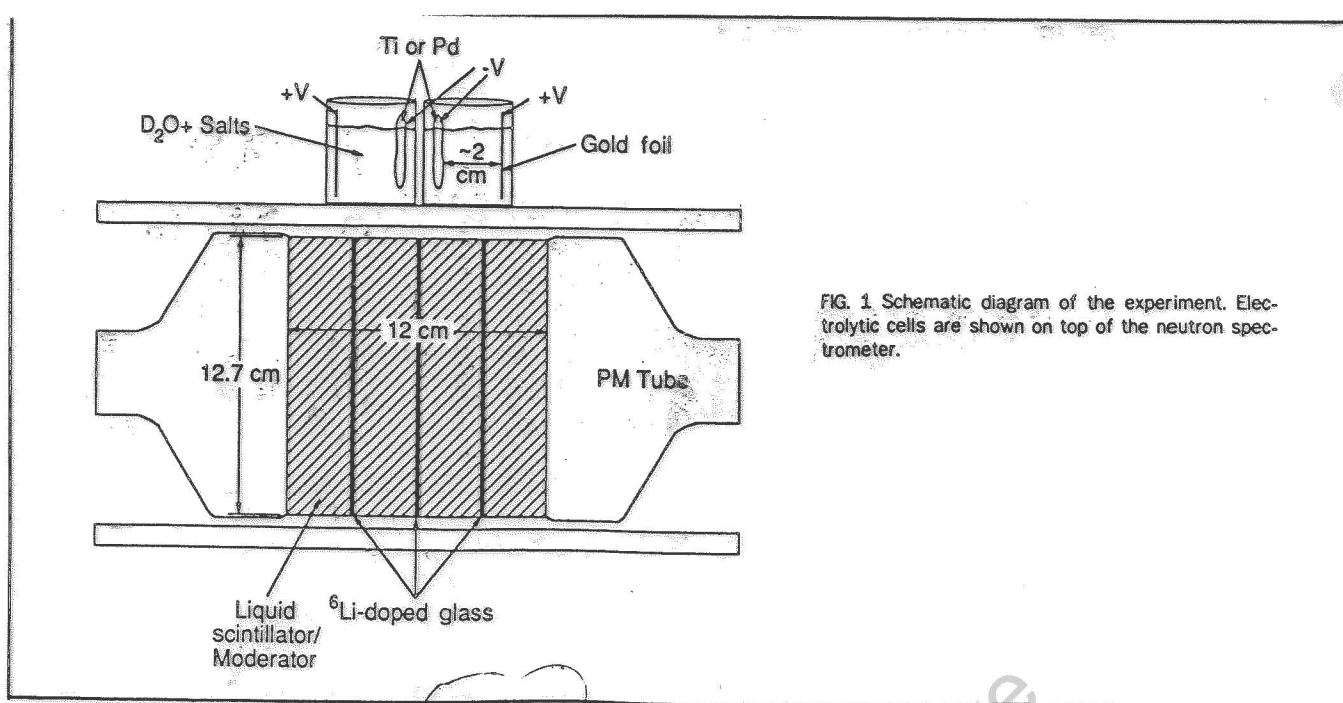
Über die während ein im günstigsten fehlte natür die Aussich um so besse Nachweise Der Versuch mußte also die Grenze zudrücken, selbe Größe erreichbar se natürlich ga heute, nach sem Problem und wollen Eine ausfü der Apparat an anderer

2.

Durch e Verfahren suchung hat auf 10^{-8} b 10^{-10} g hin wir zunächst relativ leicht siger Luft g Wasserstoff Wasser vere nicht, wie Entladungen: Platin- oder Sauerstoff Kohle entfe Glascapillare die außen m bei ihrer Fei Spektroskop schilderten bleibenden ginn der dungen in Wasserstoff, Gasen, vorb stand für de liegt nun d regung in de früher vers Helium und Eine En Verfahren n auszuführen deren Metho

¹⁾ Etwa Glas (siehe v

also see Nature 1927 etc



738

BYU

S. E. Jones, et al NATURE · VOL 338 · 27 APRIL 1989

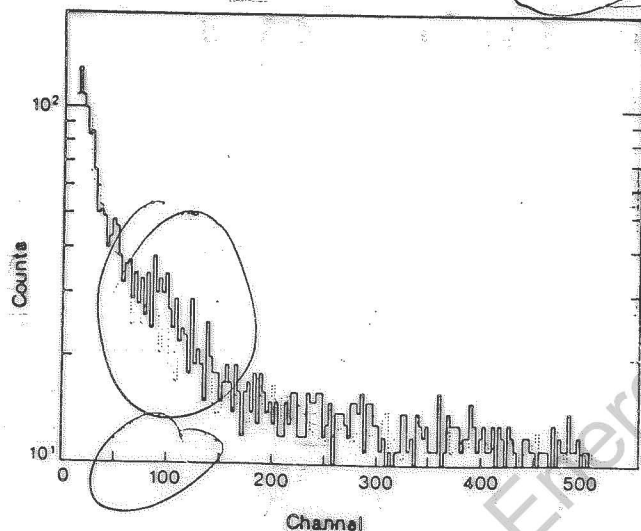


FIG. 2 Foreground (solid) and background (dashed) counts as a function of pulse height (corresponding to neutron energy) in the neutron spectrometer. Ten counts have been added to each three-channel bin for clarity of presentation.

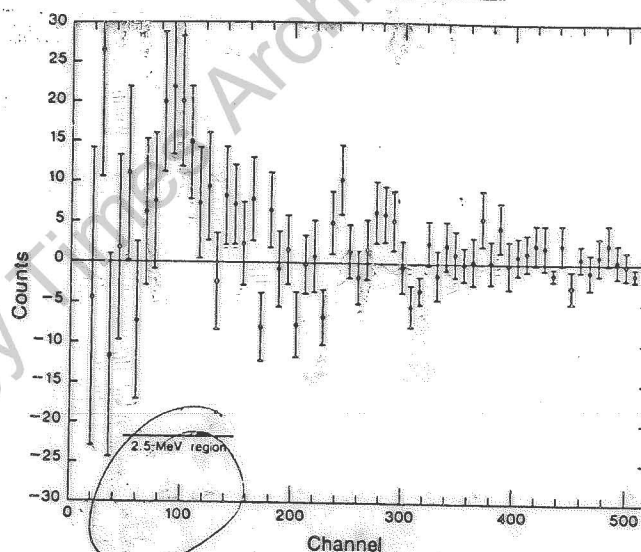


FIG. 3 Difference spectrum obtained by subtracting scaled background from the foreground. Statistical errors ($\pm 1\sigma$) are shown for each eight-channel bin.

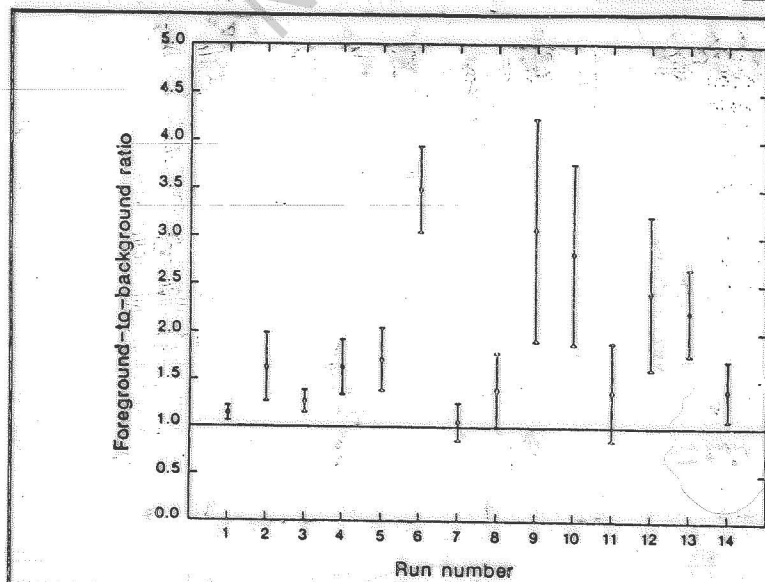


FIG. 4 Ratio of foreground rate to background rate for each run, in the 2.5-MeV energy region of the pulse-height spectrum. Statistical errors ($\pm 1\sigma$) are shown.

Date: Tue, 9 May 89 12:03:56 PDT
From: koonin@sbitp.bitnet
Message-Id: <890509120356.3be@sbitp.ucsb.edu>
Subject: report on the ecs meeting
To: perry@ohstpy.bitnet, feng@duvm.bitnet, rlg2@yktvmt.bitnet
X-ST-Vmsmail-To: ST%"perry@ohstpy.bitnet", ST%"feng@duvm.bitnet",
ST%"rlg2@yktvmt.bitnet"

May 9, 1989
11:30 PDT

There follows an eyewitness report on the special session on Electrochemically Induced Cold Fusion sponsored by The Electrochemical Society last night in Los Angeles. There were about 2000 people in attendance at the Bonaventure Hotel. No cameras or recording devices were allowed in the hall, so what follows is a somewhat subjective and incomplete report based on my notes. I will also restrict my report to what I consider new information that was presented.

PROGRAM:

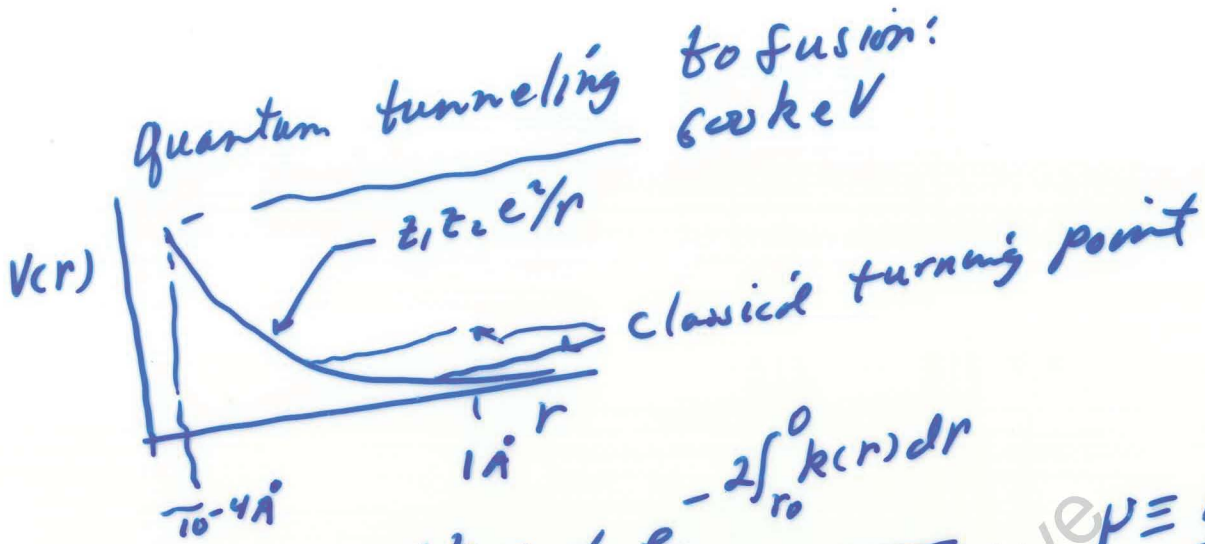
The scientific program of the meeting was:

- "Electrochemically-Induced Nuclear Fusion of Deuterium" (S. Pons and M. Fleischmann) 40 min.
- "Observation of Cold Nuclear Fusion in Condensed Matter" (S. E. Jones et al.) 25 min.
- "Thermal measurements of D-Pd and H-Pd Systems" (R. A. Huggins et al., Stanford) 15 min.
- "Observations of Heat Generation, Increased Tritium Concentration, and Enhanced Neutron Count in the Electrolysis of Deuterium Oxide on Palladium Cathodes" (U. Landau et al., Case Western Reserve) 10 min.
- "Mass Spectrometric Detection of Hydrogenic Species during Electrolysis of D2O at a Palladium Cathode" (E. Struve et al., University of Washington) 10 min.
- "Electrochemically-induced Fusion of Deuterium: The Search for Neutrons and Fusion Products" (J. Jorne et al., University of Rochester) 10 min.
- "Evidence for Excess Heat Generation During Electrolysis of D2O (Pd Cathode/ Pt Anode) in LiOD - A microcalorimetric Investigation" (S. Srinivasan et al., Texas A&M) 10 min.
- "The Fleischmann-Pons Effect: Facts and Theory at an Early Stage of Investigation" (J. Bockris et al., Texas A&M) 10 min.
- "Calorimetry, Neutron Flux, Gamma Flux, and Tritium Yield from Electrochemically Charged Palladium in D2O" (N. Lewis et al., Caltech) 10 min.

These talks were followed by about an hour of questions from the audience to all of the speakers. The (by now obligatory) press conference followed.

PONS and FLEISCHMANN:

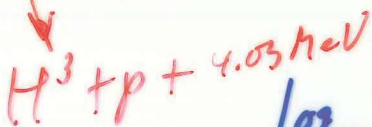
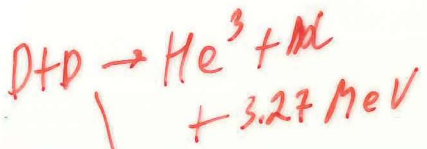
The most surprising part of the Pons-Fleischmann presentation was how little things had changed. It was basically a rehash of the same material we've been



$$\psi^2(0) \propto e^{-2 \int_0^r k(r) dr}$$

$$k = \frac{2\pi}{h} \sqrt{2\mu[V(r) - E]}$$

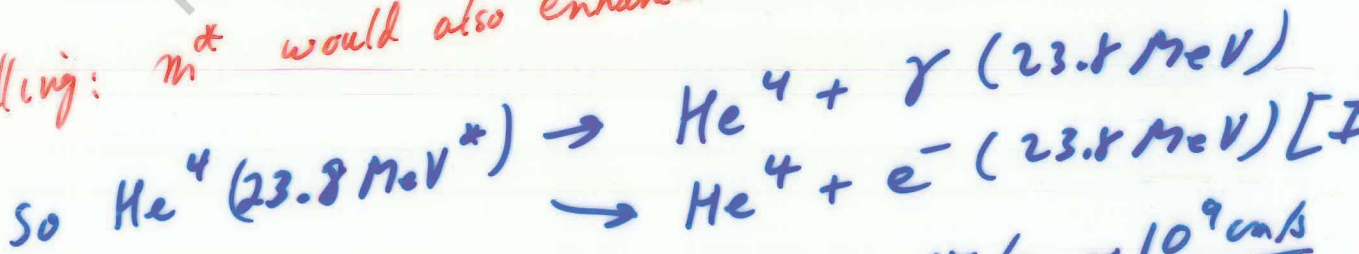
$$\mu \equiv \frac{M_1 M_2}{M_1 + M_2}$$



\log_{10} fusion rate per particle per second
in "hydrogen" molecule bound by m^*
(e.g. Komin & Naumberg 1977)

| m^*/m_e | 1 | 2 | 5 | 10 |
|-----------------|-------|-------|-------|-------|
| λ_{dd} | -63.5 | -40.4 | -19.8 | -9.1 |
| λ_{p-d} | -55.0 | -36.0 | -19.0 | -10.4 |

Warning: m^* would also enhance "internal conversion" rate (IC)



Even if $\lambda_{IC} = 10^9 \text{ s}^{-1}$, $\lambda_{(He^3+n)} \sim \frac{v_n/r_n}{10^{-12} \text{ cm}} \sim 10^{21} \text{ s}^{-1}$

(a) $\Delta E \Delta t = h \rightarrow \Delta t = \frac{h}{\Delta E} = \frac{10^{-27}}{1.6 \times 10^{-15}} = 0.6 \times 10^{-12} \text{ s} \therefore 20 \text{ keV BE}$

(b) [for a "width" of 1 eV, $\Delta E \Delta t = h \rightarrow \Delta t = \frac{h}{\Delta E} = \frac{10^{-27}}{1.6 \times 10^{-15}} = 0.6 \times 10^{-12} \text{ s} \therefore 20 \text{ keV BE}$]

04/23/89 (v)
R.L. Garwin

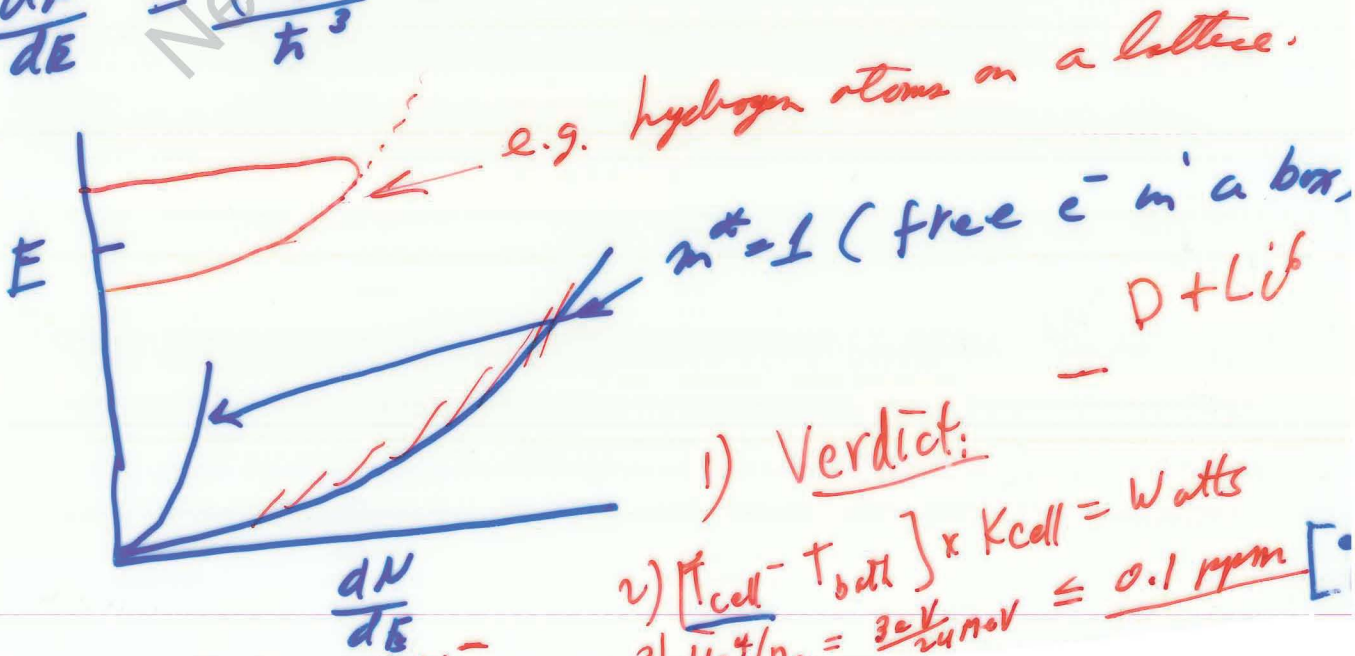
Why "Even if"?

Heavy electrons (m^*) in solid. (simple view)
number of quantum states per unit volume
with $k \leq k_{max}$ $N \approx 2 \times \frac{4\pi}{3} k_{max}^3$

but $\hbar k = p$ and $E \approx \frac{p^2}{2m^*} \approx \frac{\hbar^2 k^2}{2m^*}$

$N \approx k_m^3 \approx \left(\frac{2m^* E}{\hbar^2} \right)^{3/2} \approx \frac{m^{*3/2}}{\hbar^3} E^{3/2}$

$\frac{dN}{dE} \approx \frac{(m^*)^{3/2}}{\hbar^3} E^{1/2}$ $\propto E \propto \left(\frac{dN}{dE} \right)^2 \times \frac{1}{(m^*)^3}$



1) Verdict:

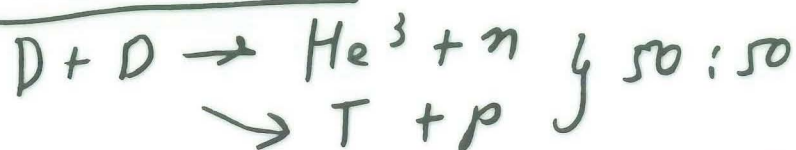
2) $(T_{cell} - T_{bath}) \times K_{cell} = \text{Watts}$
3) $\text{He}^+/\text{D}_2 = \frac{30 \text{ V}}{24 \text{ mV}} \approx 0.1 \text{ ppm}$

4) charged particles? 5) μ^-

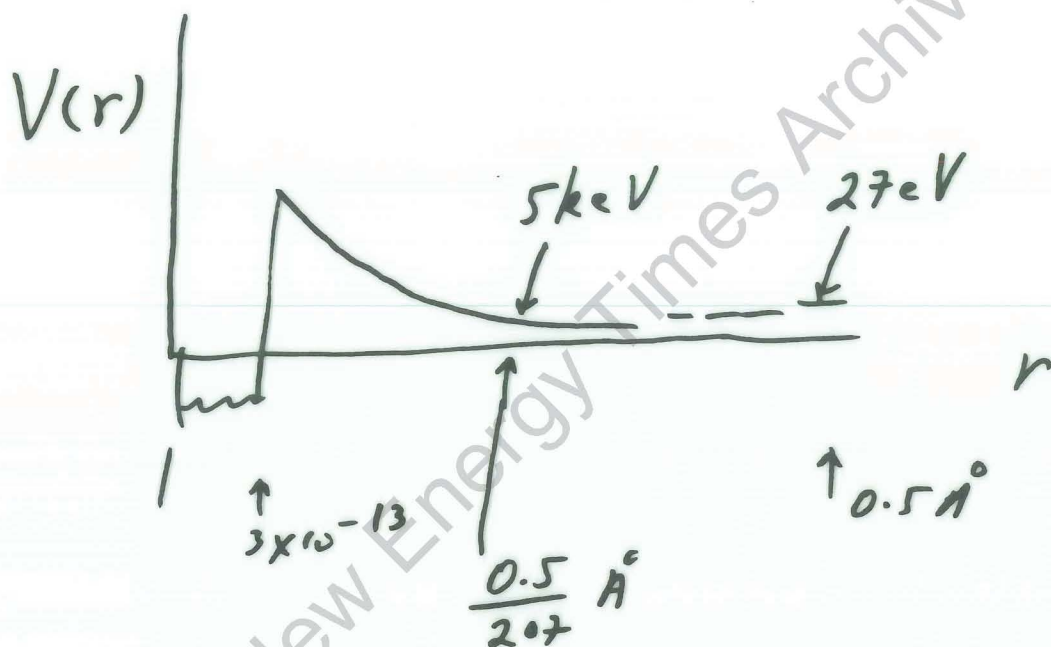
03/28/89

R. L. Garwin
(1)

Cold fusion

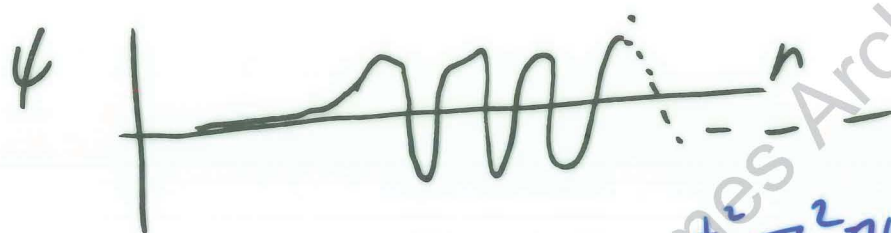
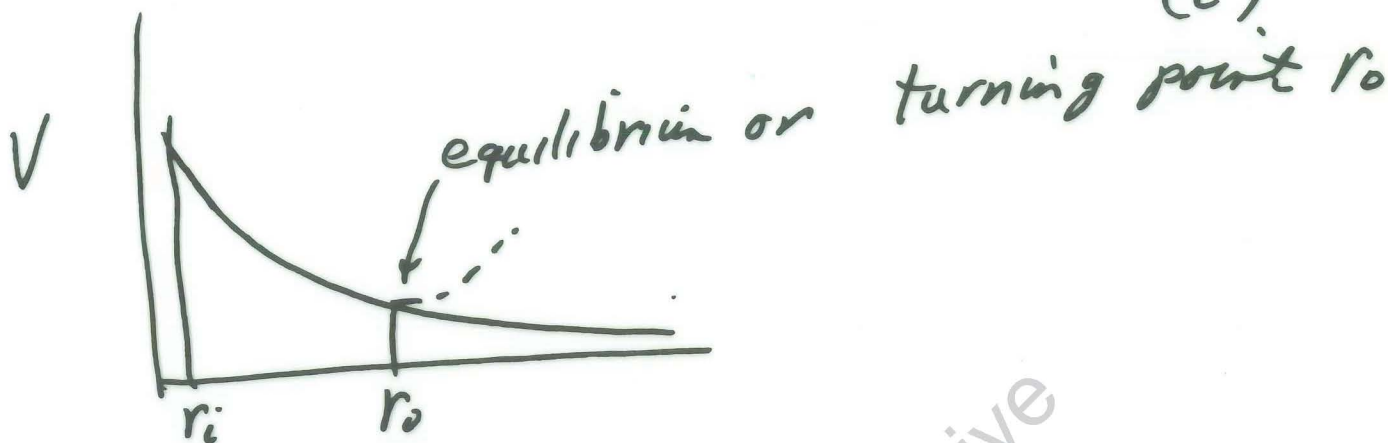


Coulomb barrier $V = \frac{e^2}{r}$ at $r = 2 \times 1.5 \times 10^{-13} \text{ cm}$
 $= 500 \text{ keV}$



- accelerator beams 10 MeV - 1 MeV - 10 keV
- thermal fusion -- ICF, H-bombs 1 keV - 100 keV (T)
- tunneling -- " , μ^- -catalyzed fusion,
Cold fusion?

03/28/89
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(2)



$$T + V = E \quad ; \quad \frac{-\hbar^2}{2m} \nabla^2 \psi = (E - V) \psi$$

$$\psi \psi = 4\pi r \psi$$

$$-\frac{\hbar^2}{2m} \frac{\partial^2 \psi}{\partial x^2} + (V - E) \psi = 0$$

let $\psi = e^{i\phi} e^{\chi}$ (should use $r\psi$)

$$e^{\chi} \psi'' + e^{\chi} \psi'^2 + \frac{2m}{\hbar^2} [E - V(x)] e^{\chi} = 0$$

$$\psi'' + \psi'^2 + \frac{2m}{\hbar^2} [E - V(x)] = 0$$

approx: $\psi' = \sqrt{\frac{2m_e e^2}{\hbar^2} \left(\frac{1}{r} - \frac{1}{r_0} \right)}$

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(3)

$$\varphi' = \left(\frac{2 m_r e^2}{\hbar^2} \right)^{1/2} \left(\frac{1}{r} - \frac{1}{r_0} \right)^{1/2}$$

$$= \left(\frac{2 \times 1.6 \times 10^{-24} \times 25 \times 10^{-20}}{10^{-54}} \right)^{1/2} ()^{1/2}$$

$$= 9 \times 10^5 ()^{1/2} \quad (R \text{ in } \text{\AA})$$

lf $r \equiv 10^{-8} R$

$$\varphi' = 0.9 \times 10^{10} \left(\frac{1}{R} - \frac{1}{R_0} \right)^{1/2}$$

$$\varphi = -0.9 \times 10^{10} \int_{R=R_0}^{R=R} \left(\frac{1}{R} - \frac{1}{R_0} \right)^{1/2} dR$$

$$\text{let } y \equiv \frac{1}{x}, \quad \varphi = +0.9 \times 10^{10} \int_{y=\frac{1}{R_0}}^{y=\frac{1}{R}} (y-y_0)^{1/2} \frac{dy}{y^2}$$

171 & # 167:

$$Y \equiv a + by + cy^2$$

$$\int \equiv -\frac{(y-y_0)^{3/2}}{y} - \left(\frac{1}{2} y_0^{1/2} \right) \sin^{-1} \left(\frac{y-2y_0}{y} \right)$$

for $y = y_0$, $\int = \frac{\pi}{4 y_0^{1/2}}$

for ~~$y = y_0$~~ $y = \infty$ ($x=0$), $\int = -\frac{\pi}{4 y_0^{1/2}} - \frac{1}{y_0^{1/2}}$

for $y = 2y_0$, $\int = -\frac{1}{2 y_0^{1/2}}$

Definite integral $\frac{1}{2} - \frac{1}{y_0} \rightarrow \frac{2.57}{y_0^{1/2}}$

for $y = 2y_0 \rightarrow \frac{1.38}{y_0^{1/2}}$

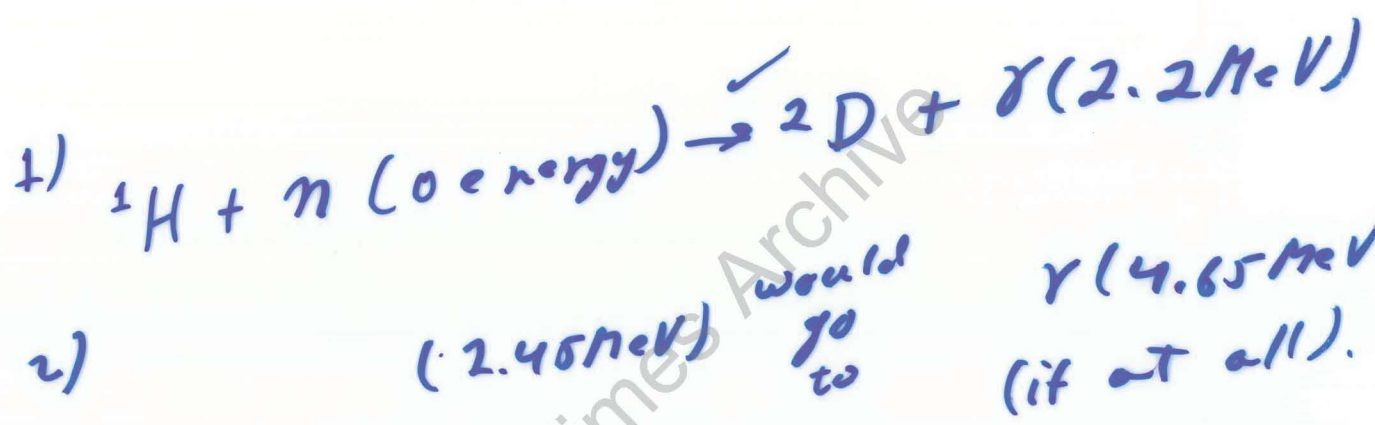
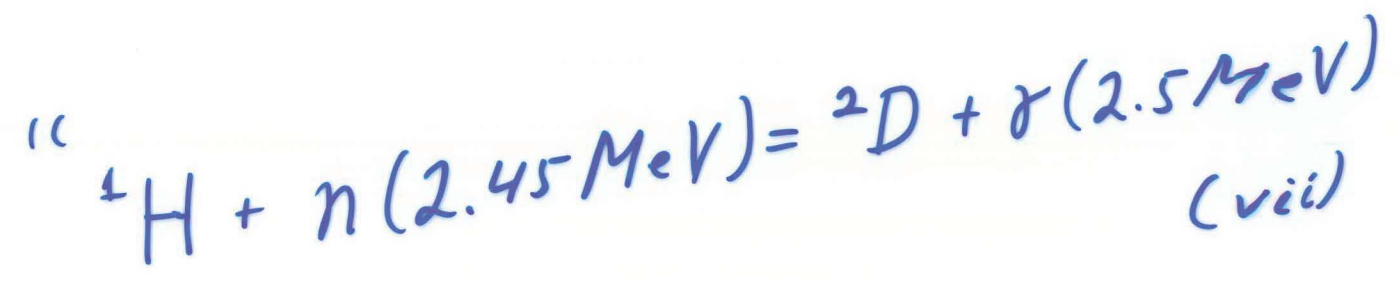
E.g., take $x = x_0/2$; $y = 2y_0$

$\varphi = \frac{-0.9 \times 10^{10}}{10^8} \times \frac{1.38}{y_0^{1/2}} = -124 x_0^{1/2}$

$\varphi = -234 \cdot x_0^{1/2}$ for $x_0 = \frac{0.5}{2.07} = 2.5 \times 10^{-3}$, $x_0^{1/2} = 0.05$

eg $\varphi = -10.6$ $2\varphi \rightarrow 21$ $2\varphi = e^{-21}$
To lose ratio of $10^{33} \rightarrow e^{76}$ we need $\varphi \rightarrow \varphi_0 - 38$
 $\varphi \rightarrow -49$, $x_0^{1/2} = 0.21$; $x_0 = 0.04 \text{ \AA}$

04/12/89 (3)



3) But neutron moderates by elastic collision with protons in water.

$$10 \text{ W/cm}^3 \times 100 \text{ hrs} \rightarrow (3.6 \times 10^5 \text{ s}) \times 10 = 4 \text{ MJ/cm}^3$$

$$4') \quad 4 \text{ MJ/cm}^3 \text{ is } \frac{4 \times 10^6 \times 10^7 \text{ erg}}{5 \times 10^{22}}$$

$$= 0.8 \times 10^{-9} \text{ erg/particle (Pd or D)}$$

$$1 \text{ eV} = 1.6 \times 10^{-12} \text{ erg, so}$$

$$4 \text{ MJ/cm}^3 \text{ is } 500 \text{ eV per D.}$$

Chemical energies $\leq 3 \text{ eV}$ per particle

— At $\sim 10 \text{ MeV}$ per fusion,

$$500 \text{ eV/D is } \frac{5 \times 10^2}{10^7} = 5 \times 10^{-5} \text{ f/D --}$$

— so product should readily be seen.

$$10 \text{ W/cm}^3 \text{ is } 6 \times 10^{13} \text{ MeV/cm}^3 \text{ sec}$$

$$\sim \frac{6 \times 10^{12} \text{ fusions/cm}^3 \text{ sec}}{\sim 4000 \gamma/\text{sec}} \left. \vphantom{\frac{6 \times 10^{12} \text{ fusions/cm}^3 \text{ sec}}{\sim 4000 \gamma/\text{sec}}} \right\} \text{F-P}$$

— Can't be D-D or even P-D.

If $\text{D} + \text{Li}^6$ were possible $\xrightarrow{22.4 \text{ MeV}} \text{Be}^8 \rightarrow \text{He}^4 + \text{He}^4$
 $\text{P} + \text{Li}^7$ would be much faster. 17.3 MeV

No mechanism known to permit this.



04/12/89

Questions provoked by experiments:

BYU-(1) Are neutrons generated by the electrolysis? [Crucial question]

(1.1) If so, how reproduce & optimize?

(1.2) Why not vast amount of data since 03/23/89?

U.U. --

(2) Gamma rays.

(2.1) Display full spectrum -- escape peaks, etc.;

(2.2) Claim: "Spectrum confirms that 2.45 MeV neutrons are indeed generated"! -- X

- no such reaction; no such energy of γ .

(2.3) gammas associated with heat?

- [How to do xpt.]

(3) neutrons -- when?

(4) heat --

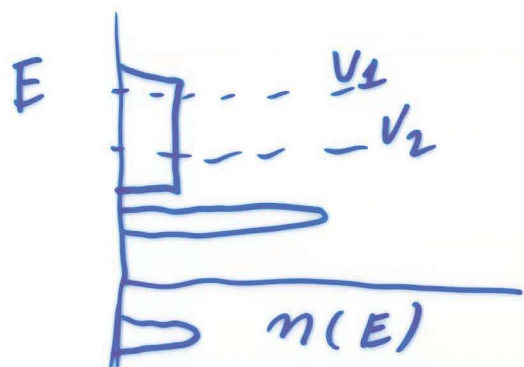
(4.1) Explosive release. Why not chemical?

(4.2) Steady release -- run-by-run details.
Other sources -- e.g. $D_2 + \text{air}$?? Stir?
why not Stir?

04/12/89 (4)

U.U.1

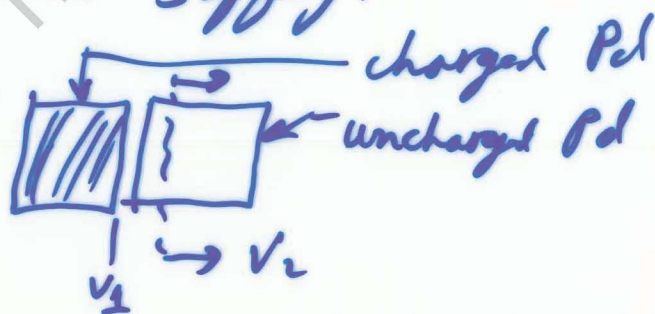
What is disruptive pressure in PdH_x ?



Notional density of states vs. energy of sites.

- Electrolyze to charge sites with D. [“diffusion time”]
- Cut off electrical supply.

$$\Delta E = P \Delta V$$



$$\text{So } p \sim E \cdot n$$

$$\sim \frac{1 \text{ eV} \cdot 5 \times 10^{22} \text{ sp/cm}^3}{1.6 \times 10^{-12}}$$

$$= 8 \times 10^{10} = \underline{\underline{80,000 \text{ atm}}}$$

So:

U.U (cont).

04/12/89 (2)

(5) Tritium.

Quantity in D_2O feed? 100 dpm/ml
measured

- Data from J. Bigeleisen

-- $100 - 200 \text{ dpm/ml}$ in D_2O .

-- "P-D separation factor 9.5."

(6) How negate "arcs and sparks"
hypothesis?

(7) Contribute Lond "charged"
cathodes to other Labs?

New Energy Times Archive

Cold Nuclear Fusion 05/09/89

03/23/89 -- U.U. < Pons, S.
Fleischmann, M.
Hawkins, M.

-- BYU < Jones, S.E.
Palmer, R.P.; Czirr, J.B.;
Decker, D.L.; Jensen, G.L.;
Thorne, J.M.; Taylor, S.F.;
Rafelski, J.

BYU -- 170 counts ± 23

UU -- Heat!

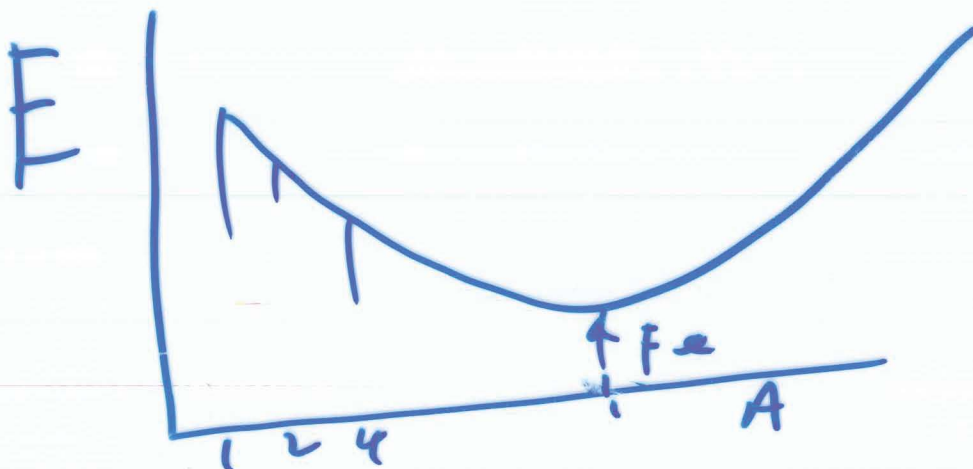
$\sim 1 \text{ watt}$

- neutrons (gammas --) $\sim 10^3 \text{ s}^{-1}$

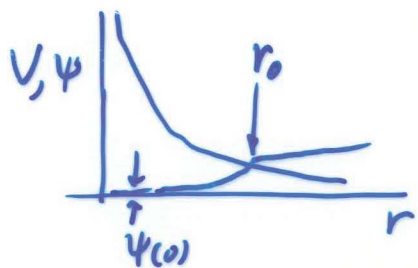
- tritium (3H) $\sim 100 \text{ dpm/ml}$

- ^4He

$\sim 10^{12} \text{ s}^{-1}$



04/11/89



$$\frac{\psi(0)}{\psi(r_0)} = e^{-\varphi} \quad \varphi \propto m_r^{1/2}$$

for D-D, $m_r = 1 \text{ a.m.u.}$; $\varphi = 231 r_0^{1/2}$ (r_0 in Å)

P-D, $m_r = 2/3 \text{ a.m.u.}$; $\varphi = 189 r_0^{1/2}$

D-D_p, $m_r \sim 1 \text{ a.m.u.}$; $r_0 = \frac{0.74}{200}$; $\varphi = 14$. Rate $\sim 10^6 \text{ s}^{-1}$

By comparison with D-D_p, D-D_e

is slower by $e^{(24(r_0^{1/2}) - 24r_0)} = e^{462 r_0^{1/2} - 28}$

for this rate to be $10^{-23} \text{ sec}^{-1}$ (10^{29} times slower than D-D_p)

the exponent must be $e^{29 \times 2.303} = e^{67}$ larger

so that $462 r_0^{1/2} = 28 + 67$; $r_0^{1/2} = 0.205$; $r_0 = 0.04 \text{ Å}$

thus $m^*/m_e = \frac{0.74}{0.04} = \underline{\underline{18.5}}$.

If we are seeing something like P-D, $r_0 \sim 0.0625$

$$\frac{m^*}{m_e} = \underline{\underline{12}}.$$

Cold nuclear fusion

05/12/89

NSB mtg.
(R.L. Garwin)

The Creation -- 03/23/89

U.U.

BYU

(but)

press Conferences + mtgs:

04/12/89 Eric (Sicily)

05/01-02/89 APS (Baltimore)

05/08/89 El.chem. Soc. (Los Angeles)

the Nay-sayers / finders.

the once-Confirmers.

the maintainers

Congressional response

DOE response

Comments on Communications

05/12/89

Texas A&M reported 05/08:

1) S. Srinivasan, et al. Microcalorimetry $10^6 - 8 W$.

Pd rods 0.5 mm ϕ 1 mm diam x 10 mm long.

also 2-mm diam sphere

$\sim 1/3$ of 20 cells show "excess heat"

Best 30 mW (10% more than power in)

2) John Bockris reporting on Kevin Wolf.

2/20 cells were "live" -- one reproducible

Some neutrons seen in S.C.

$\leq 50 n/min$.

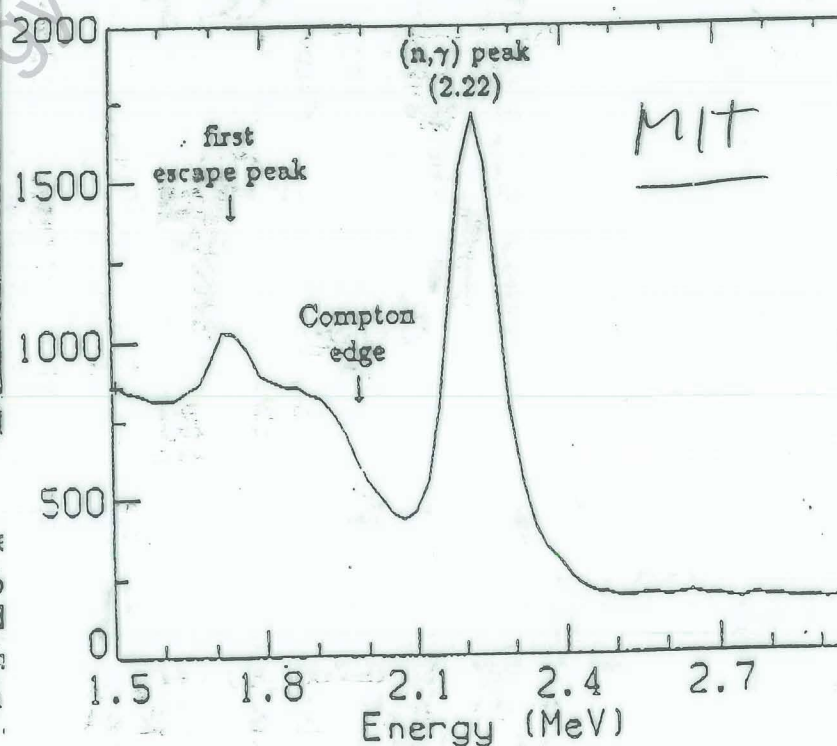
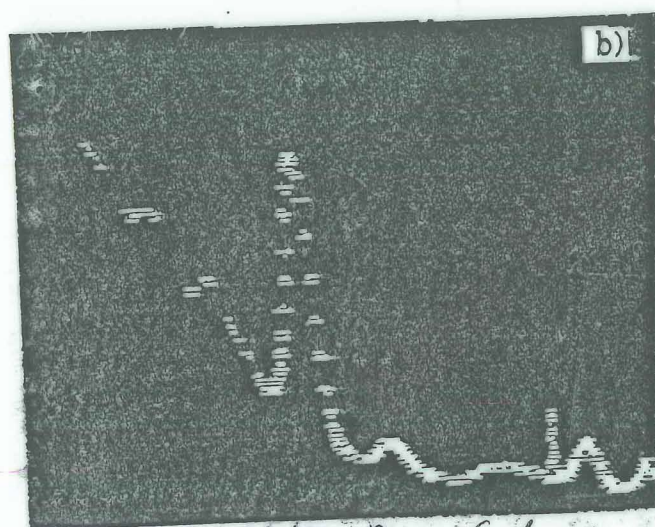
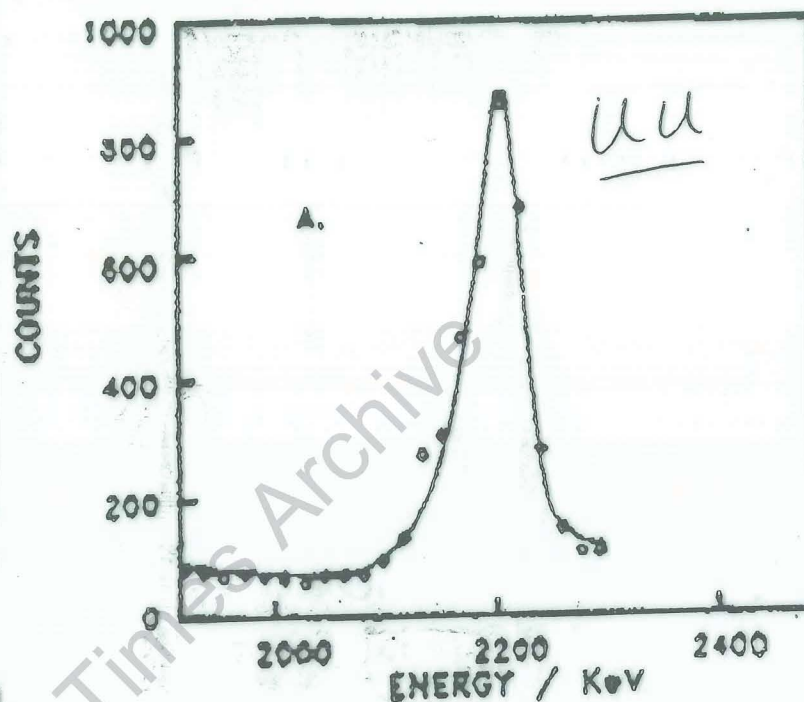
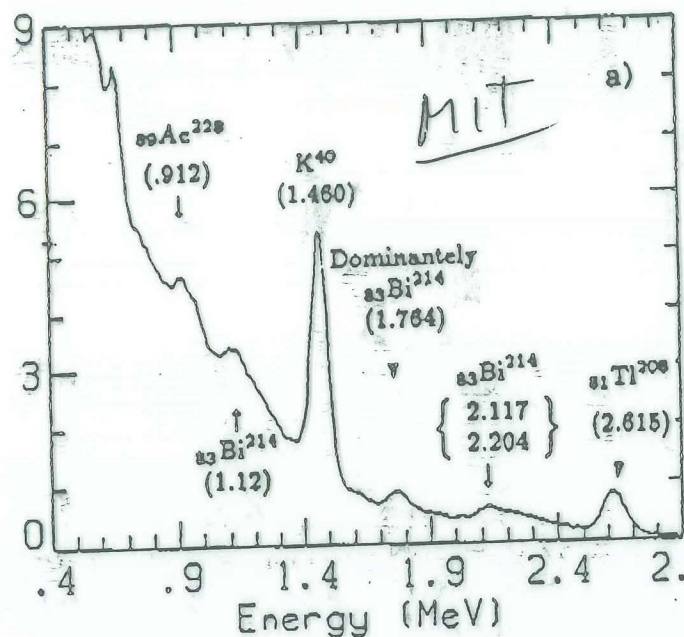
Tritium detected

"60-80 dpm/ml in D_2O

$\rightarrow 10^6$ dpm/ml after a few hours"

3) Nate Lewis, Caltech

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comparison of the γ -ray background spectrum measured by a NaI(Tl) detector at MIT (top) and the γ -ray spectrum shown on television (bottom). a) The background spectrum measured by a NaI(Tl) detector at MIT. Some important terrestrial isotopes have been identified in this figure. The spectrum is from an 84-hour run. b) The γ -ray spectrum of FPH2. The characteristics of the two spectra are similar; one of the two detectors have comparable spectral resolution. b, note the curious structure at about 2.5 MeV and the ^{208}Tl peak (2.61 MeV), which appear to be artifacts of the spectrum. The spectrum can be obtained from KSL-TV in Utah.

γ -ray spectrum measured by a 3" x 3" NaI(Tl) spectrometer in a neutron-capture-on-hydrogen experiment, which utilized a (PuBe) neutron source submerged in water. Because of the size of the crystal (which is identical to that of FPH2), the

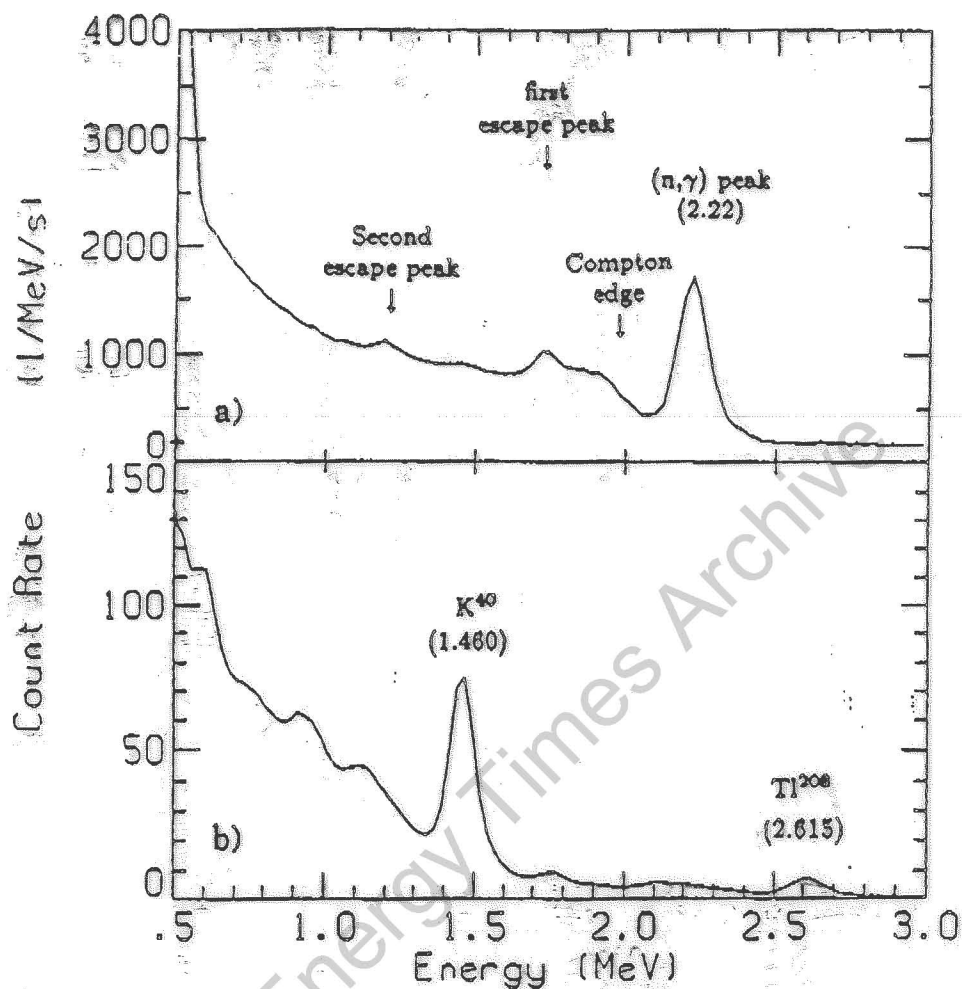


Fig. 4

The full γ -ray spectrum measured at MIT in a neutron-capture-on-hydrogen experiment, which utilized a (PuBe) neutron source submerged in water. a) The γ -ray spectrum due to (n, γ) reaction. One can see the single and double pair escape peaks, and of particular importance to this paper, the Compton edge. b) The γ -ray background measured with the same experimental setup and at the same location during a 24-hour period prior to the neutron experiment. The vertical scale in the figure is in counts per 100 minutes. See Citation 5 for the experimental arrangement.

γ -Ray Spectra in the Fleischmann,
Pons, Hawkins Experiment

(617) 425-5553

R. D. Petrasso, X. Chen, K. W. Wenzel,
R. R. Parker, C. K. Li, and C. Fiore
Plasma Fusion Center
Massachusetts Institute of Technology
Cambridge, MA 02139

April 1989

→ Nature

Electrochemically Induced Nuclear Fusion of Deuterium

Martin Fleischmann
Department of Chemistry
The University
Southampton, Hants. SO9 5NH
ENGLAND

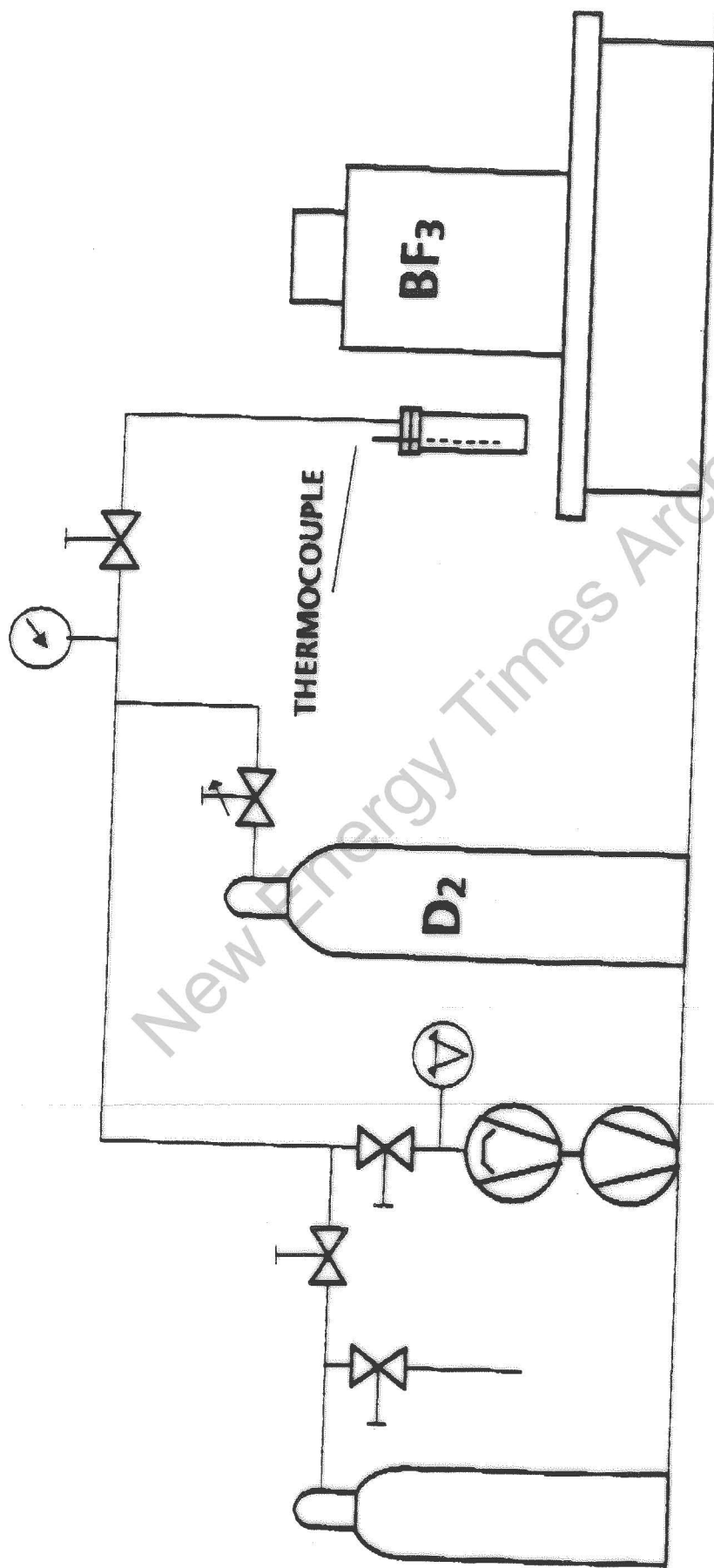
Eq. vi on p 3.51?
8.4??

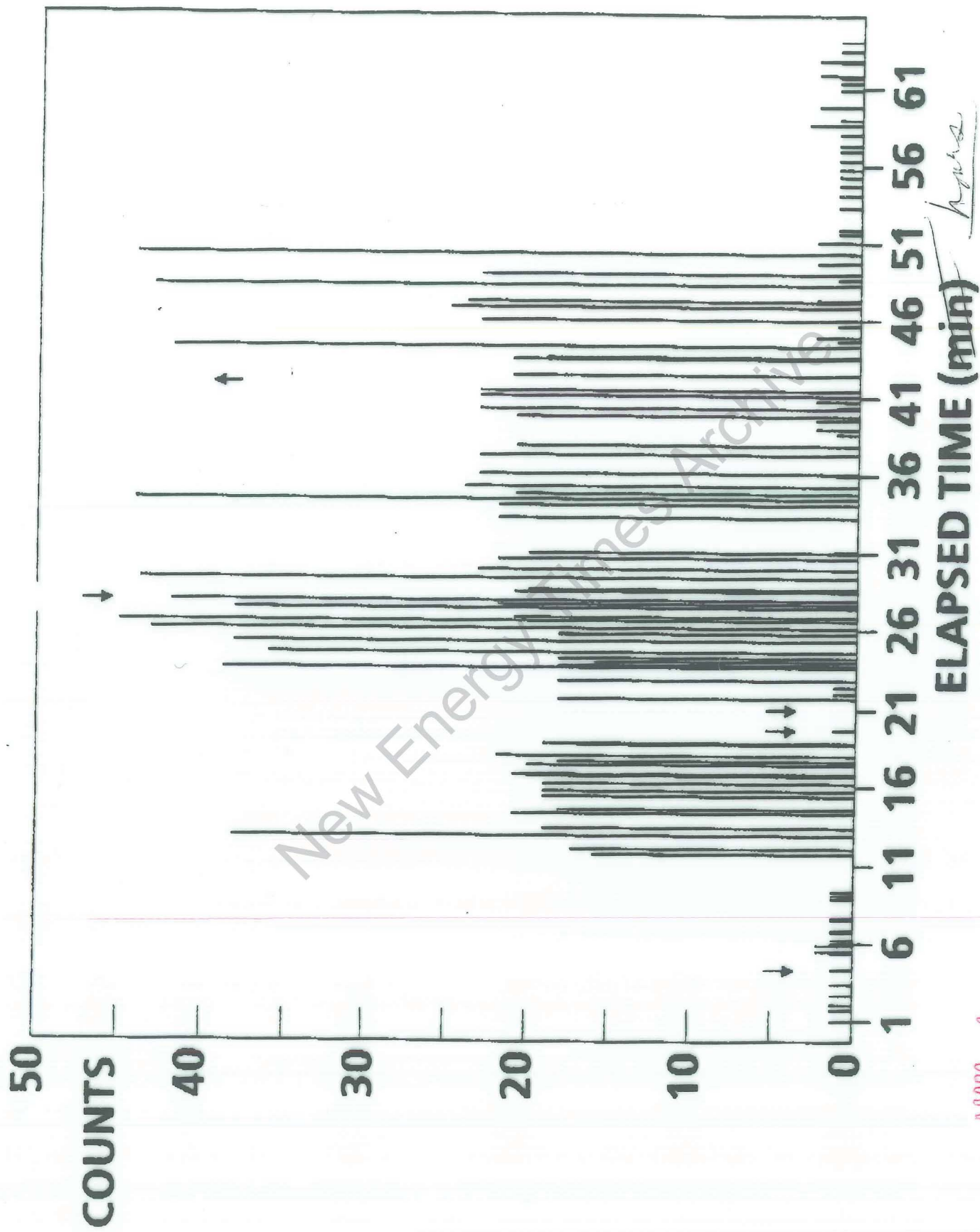
Fig 2??
8.3 Bejebesin

Stanley Pons*
Department of Chemistry
University of Utah
Salt Lake City, UT 84112 USA

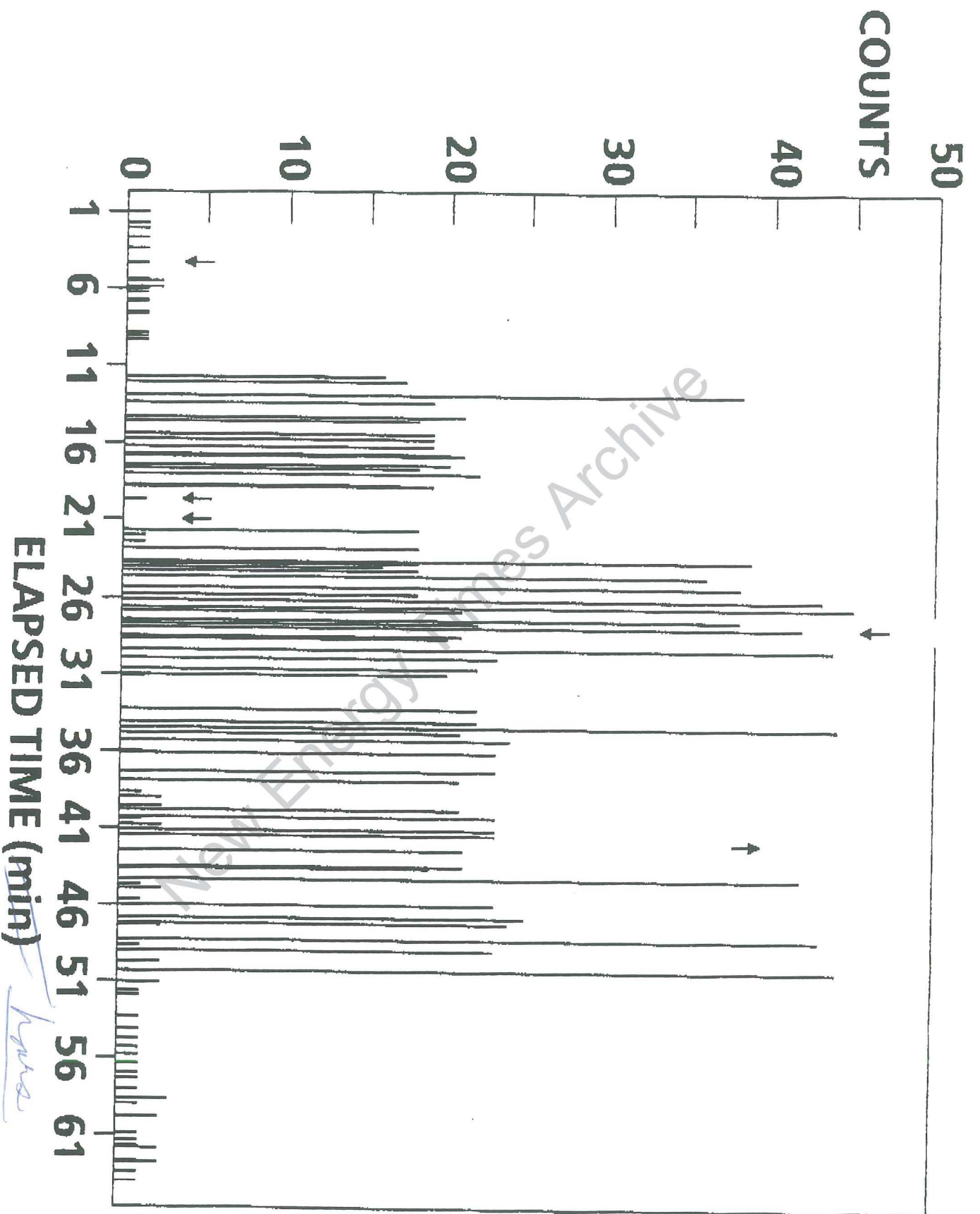
Submitted to Journal of Electroanalytical Chemistry March 11, 1989; in final form March 20, 1989.

*To whom correspondence should be addressed.

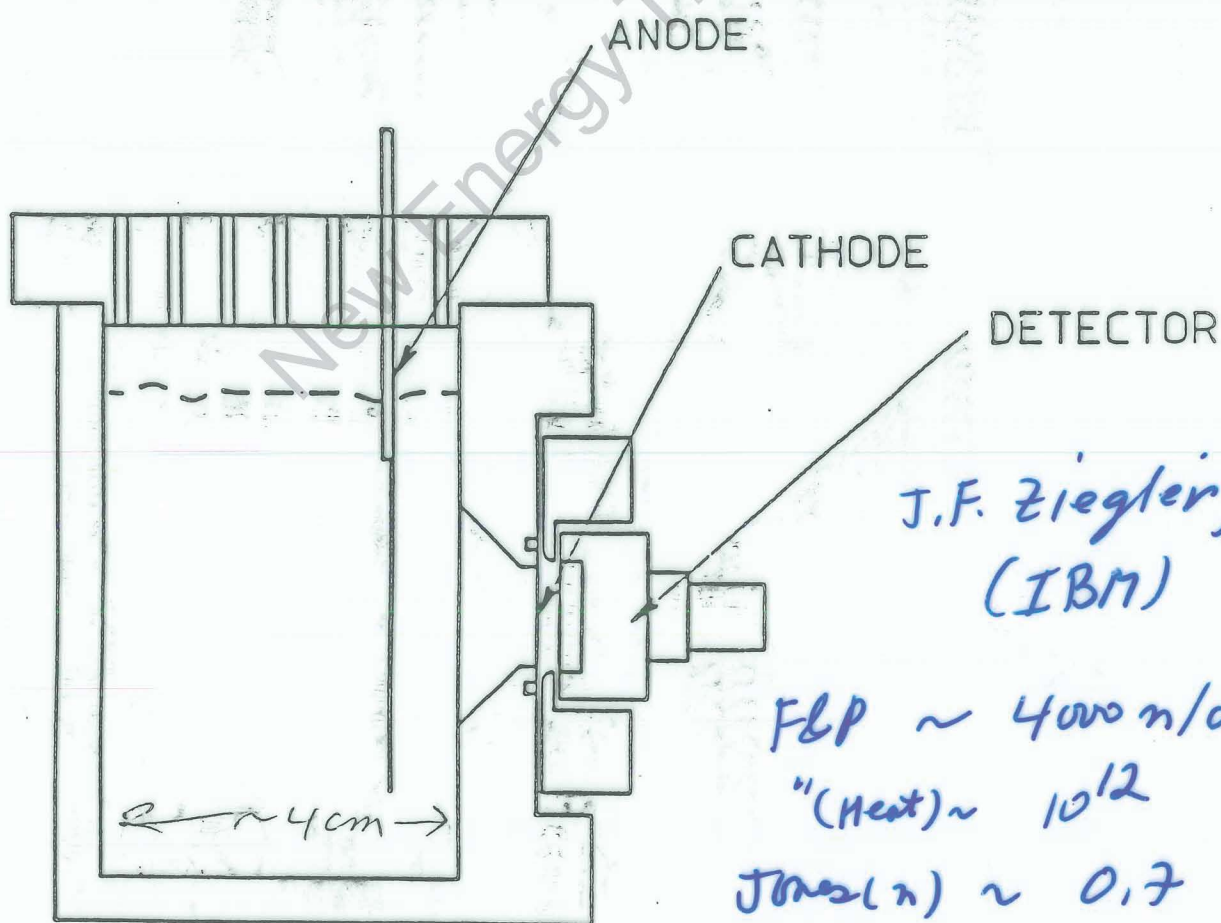
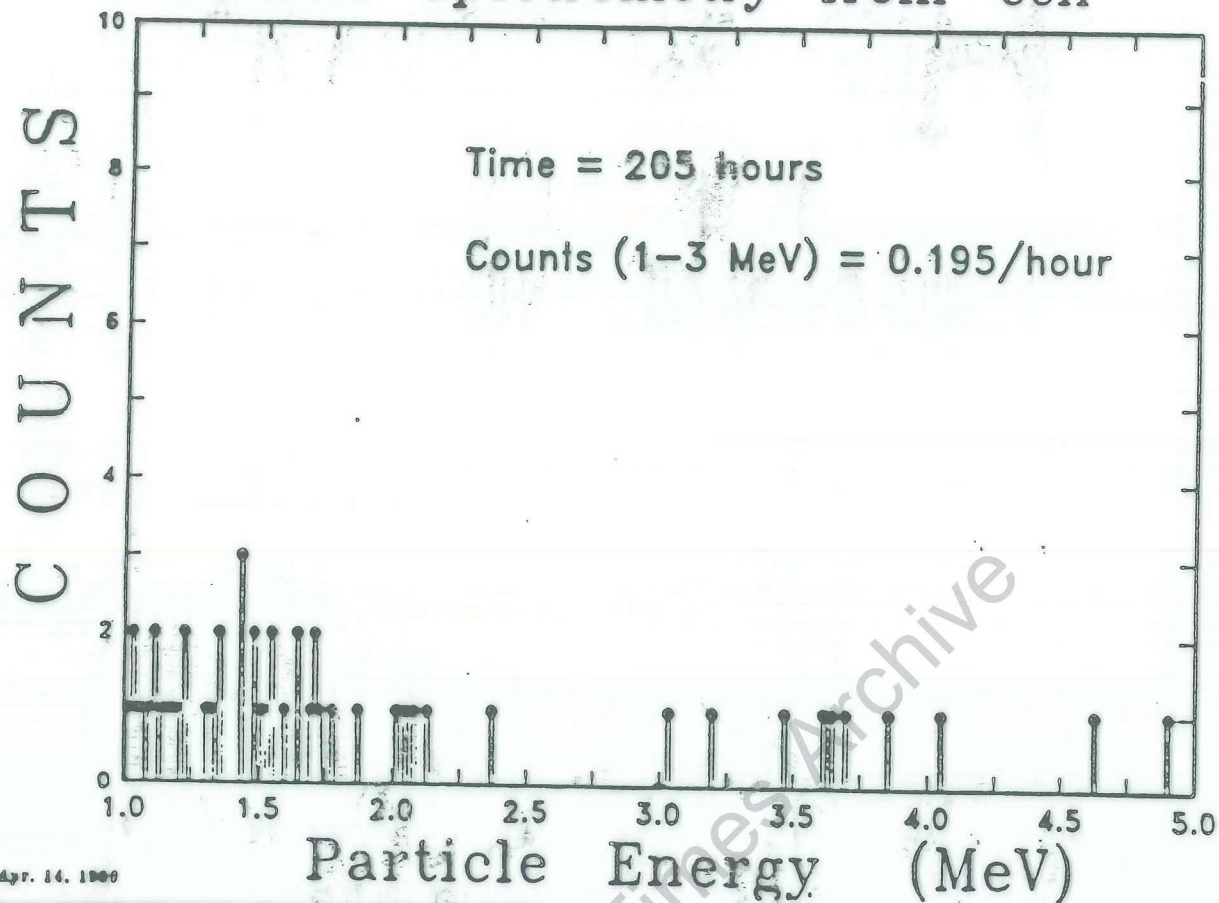




60 μ sec



Particle Spectrometry from Cell



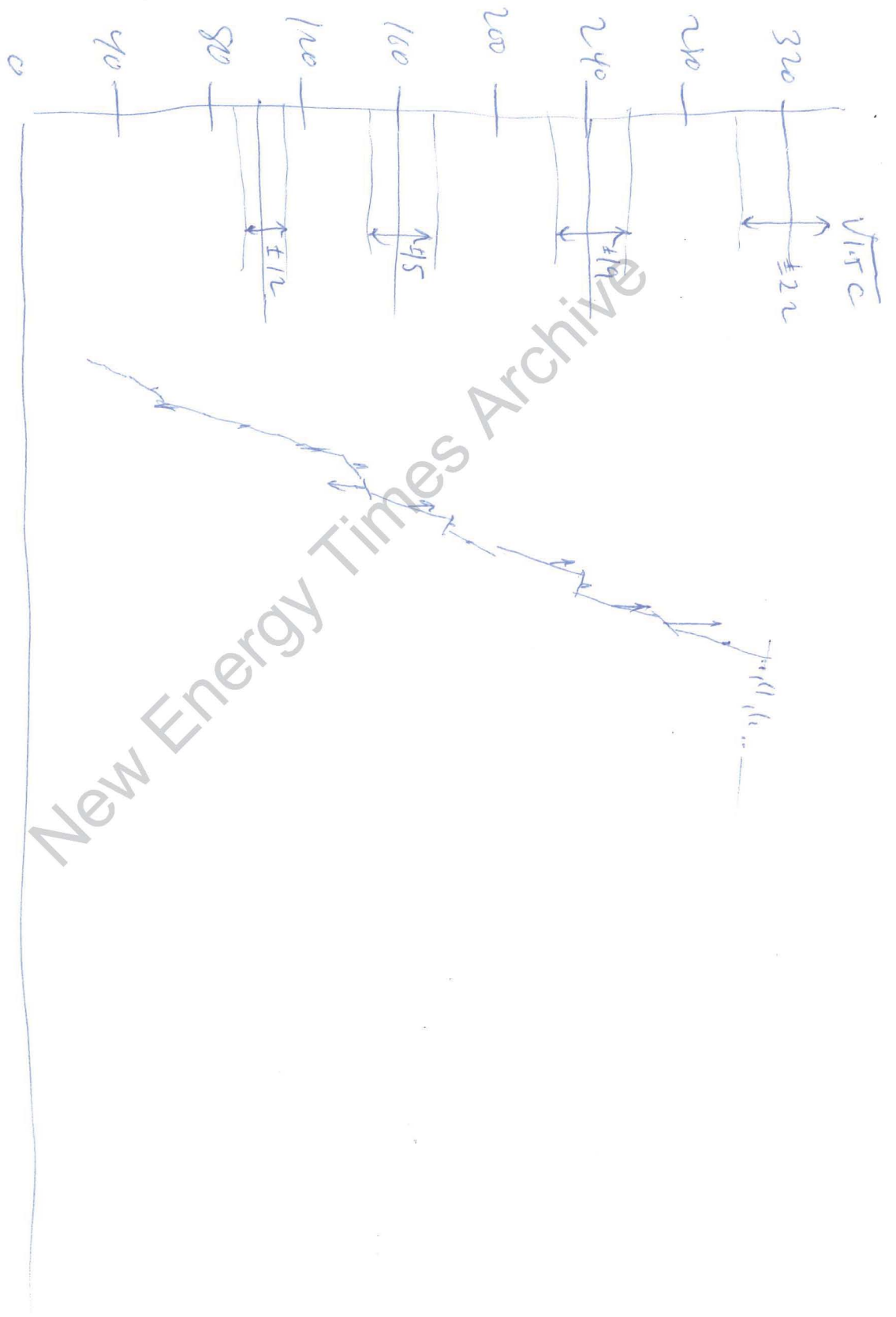
J.F. Ziegler, et al
(IBM)

FLP $\sim 4000 \text{ n/cm}^2\text{-s}$

"(Heat) $\sim 10^{12}$

$J_{\text{max}}(n) \sim 0.7$

IBM (t, p) $\leq 0.005 / \text{cm}^2\text{-s}$



C
320

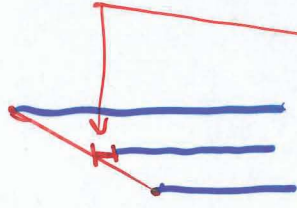
$\sqrt{1.5C}$

± 22

± 19

± 15

± 12



Standard deviation of a single point should be $C^{1/2}$
S.D. of a point from the average of adjacent points should be $\sqrt{1.5C}$

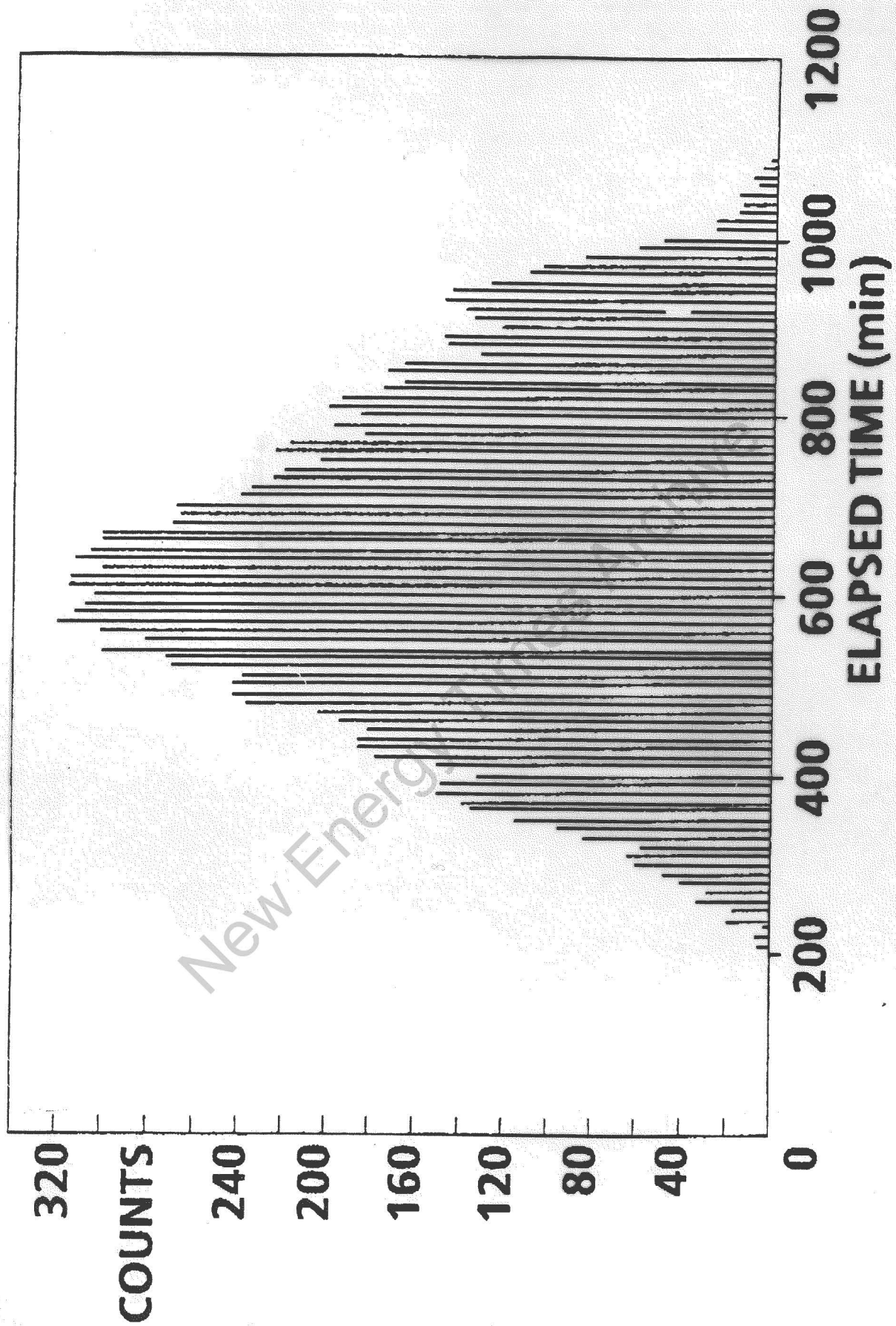


TABLE 1. Generation of excess enthalpy in Pd-cathodes as a function of current density and electrode size.

| electrode type | dimensions | current density /mA cm ⁻² | excess rate of heating / watt cm ⁻³ | excess specific rate of heating/watt cm ⁻³ | current density /mA cm ⁻² | excess rate of Heating/watt | excess specific rate of Heating/watt cm ⁻³ | current density /mA cm ⁻² | excess rate of Heating/watt | excess specific rate of Heating/watt cm ⁻³ |
|----------------|------------|---|---|--|---|--------------------------------|--|---|--------------------------------|--|
| Rods | 0.1x10cm | 8 | .0075 | .095 | 64 | .079 | 1.01 | 512 | .654 | 8.33 |
| | 0.2x10cm | 8 | .036 | .115 | 64 | .493 | 1.57 | 512 | 3.02 | 9.61 |
| | 0.4x10cm | 8 | .153 | .122 | 64 | 1.751 | 1.39 | 512 | 26.8 | 21.4 |
| Sheet | 0.2x8x8cm | 0.8 | .153 | 0.0080 | 1.2 | .027 | .0021 | 1.6 | .079 | .0061 |
| Cube | 1x1x1cm | 125 | WARNING! IGNITION? see text! | | 250 | | | | | |

* Measured on electrodes of length 1.25cm and rescaled to 10cm.

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04/12/89

TABLE 2. Generation of excess enthalpy in Pd rod cathodes expressed as a percentage of breakeven values.

| electrode type | dimensions | current density /mA cm ⁻² | excess heating [*] /% of breakeven | excess heating ^{**} /% of breakeven | excess heating ^{***} /% of breakeven | current density /mA cm ⁻² | excess heating [*] /% of breakeven | excess heating ^{**} /% of breakeven | excess heating ^{***} /% of breakeven | current density /mA cm ⁻² | excess heating [*] /% of breakeven | excess heating ^{**} /% of breakeven | excess heating ^{***} /% of breakeven |
|----------------|------------|---|--|---|--|---|--|---|--|---|--|---|--|
| Rods | 0.1x10cm | 8 | 23 | 12 | 60 | 64 | 19 | 11 | 79 | 512 | 5 | 5 | 81 |
| | 0.2x10cm | 8 | 62 | 27 | 286 | 64 | 46 | 29 | 247 | 512 | 14 | 11 | 185 |
| | 0.4x10cm | 8 | 111 | 53 | 1224 | 64 | 66 | 45 | 438 | 512 | 59 | 48 | 839 |

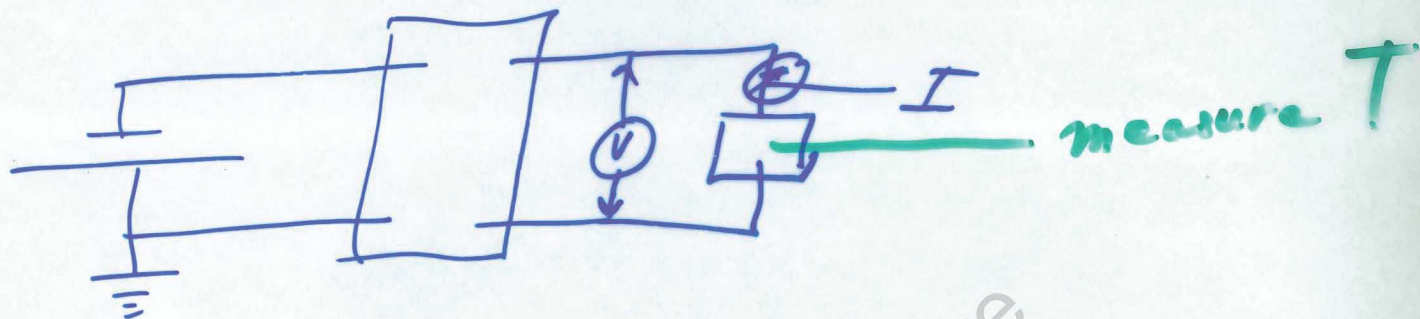
* % of breakeven based on Joule heat supplied to cell and anode reaction $40D^- \rightarrow 2D_2O + O_2 + 4e$

** % of breakeven based on total energy supplied to cell and anode reaction $40D^- \rightarrow 2D_2O + O_2 + 4e$

*** % of breakeven based on total energy supplied to cell and for an electrode reaction $D_2 + 20D^- \rightarrow 2D_2O + 4e$ with a cell potential of 0.5V.

05/12/89

Not even so easy to calculate ^[1]
 "power in"!



I have put in $I = 0.1 \text{ A}$

$V = 200 \text{ V}$

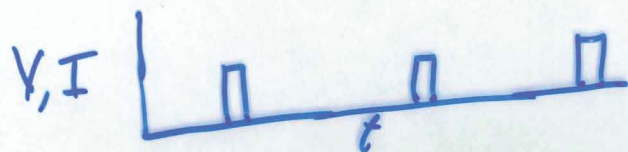
and dissipated $200 \text{ W} \gg V \times I$

$$\bar{P} = \langle V(t) \cdot I(t) \rangle$$

If V is constant $\bar{P} = V \langle I(t) \rangle$

If I is constant $\bar{P} = \langle V(t) \rangle I$

But if not, $\bar{P} \neq \langle V(t) \rangle \times \langle I(t) \rangle$



R. L. Garwin